A Retrospective Study of Measures Taken to Prevent Over-the-Embankment Motor Vehicle Crashes in the Hoopa Area of Northern California. David C. Short, Class of 1988.

"About 8000 occupants are killed each year in vehicles that overturn. Death rates for such "rollover" crashes, which are highest in the mountain states are related not only to the gradient and curvature of roads, but also to the absence of recovery areas and guardrails where vehicles leaving the roadway can roll down an embankment."[2]

"Rollovers have high death-rates,more than twice the rate for non-rollovers. This is partly because a much larger proportion of occupants (8 percent) are ejected from their vehicles in rollovers, compared to only 0.4 percent ejected from vehicles that do not roll over. Ejection is associated with a 25-fold increase in the risk of death: 259 deaths per 1,000 people ejected compared to about 10 per 1,000 among those not ejected. The ability of a vehicle to keep occupants inside when it crashes (whether or not the vehicle overturns) is a major determinant of the likelihood of severe injury or death."[3]

"The ratio of occupant deaths to injuries increases dramatically with the posted speed limit, from less than 4 deaths per 1,000 injuries where the limit is 30 MPH or less, to 25 per 1,000 where the limit is 55 MPH."[3]

Hall et al.[4] studied the nature of single vehicle accidents involving fixed objects along the roadside and found that these accidents occurred most frequently during darkness and/or adverse weather, on poor pavement, and on horizontal curves."[5]

Given the above information, it is not surprising that the area round Hoopa, California, has a very high severe injury and death rate: A high percentage of the crashes occur over the bank and result in extended rollover type crashes which often eject the occupants. It is common to find some of the occupants of an over the bank standing on the side of the road claiming to have "jumped out" early in the crash. Often these people will have only minor injuries while those who remained in the vehicle longer are ejected with more force and receive much more severe injuries. Highway conditions in the Hoopa area are universally poor. Crooked roads with narrow shoulders and rough surfaces are the rule. Elevation of the roadway changes rapidly. Weather is inclement during much of the year with mud and debris scattered across the roadway after each rain, freeze, or thaw. Large-truck traffic is frequently heavy. These trucks spill fuel and oil over the roadway causing slick surfaces, especially during the first rains after a dry spell. Large vehicles on steep grades cause congestion problems going up and speed-control problems coming down. The average speed limit is 55 MPH.

The Hoopa Indian reservation has a very high rate of unemployment (85%). Many of the vehicles are substandard older cars in questionable repair. Four-wheel drive vehicles are popular, and it is also popular to jack them up and put oversized tires on them raising their center of gravity and causing poor handling characteristics in the turns. The nearest definitive medical care is 52 miles from downtown Hoopa, which translates into about 2 hours from the more remote areas of the response zone.

Along certain stretches of these roads are areas known locally as "the bluffs". These are areas where the road traverses a particularly steep hillside, usually high above the river. Because they cross such steep terrain, these bluffs tend to be extremely narrow, crooked, and rough. They have more than the usual amount of debris problems, and usually very narrow shoulders, or no shoulders at all. The bluffs are often over 500 feet high. For many years, the only protection to vehicles traveling the bluff areas were logs which were anchored along the roadside edge forming a low barrier. These prevented a vehicle from being sucked over by a carelessly placed outside wheel, but they did little to prevent vehicles from plunging over when the log barriers were hit with any force, or at a more acute angle.

Although this study addresses over-the-bank crashes from the years 1979 through 1988, it is the bluffs which are the primary focus for improvement. This study will demonstrate that the bluff areas are over-represented for fatal and critical injuries from all motor vehicle crashes within our area. It will further show that the nature of these fatal injuries is primarily major multiple-systems trauma.

Narrative

As EMS Coordinator and also as a rescuer, I have long been interested in the problem of over-the-bank vehicle crashes. The bluffs in particular presented a major hazard because of their height, extreme steepness, and the difficulty and dangers associated with performing technical rescue as well as advanced life support below loose rocks. For the first five years, the entire plan was based on accessing the patient, removing him from the danger of falling rocks, stabilizing him if possible, and extricating him from the hillside. These efforts met with limited success. Time and the severity of the injuries always worked against us. Usually if the patient was in critical condition when we got to him, he was dead by the time we reached the hospital. These patients needed a trauma surgeon and whole blood within one hour of their injury, and frequently the total time of the incident would exceed three hours.

I want to emphasize here that EMS has played an important part in patient survival in our area. Being forced to deal with these extremely complex and hazardous rescues forced the entire region's EMS into vast improvements. Those improvements have had far-reaching consequences throughout our response zone. However, in patients with major multiple-systems trauma, the chances of survival were very slim, and continue to be at this time. As I began to see the futility of treating these multiple-trauma patients after the fact, I became more sensitive to the idea that prevention is the only real answer in this case. We had done all we could for the patients and our success ratio hadn't changed at all.

I began a program of video taping the areas where our most severe problems were occurring. I went out in uniform with an ambulance unit and taped road features, embankments, shoulder widths, and skid marks after crashes. I began this program in 1985. My plan was to come up with a strong argument that I could take to Cal-Trans which would help speed up the process of building barriers to the embankments along the high risk areas.

Coincidentally with my filming campaign, Cal-Trans found itself at fault in two substantial lawsuits: one for inadequate road width and one for actions taken by their crew at the scene of a diesel spill which caused a double fatality in the North Hoopa Bluffs. There was a substantial financial settlement by Cal-Trans in each of these suits. Also, in 1985, a Mr. Jim Siebert, a Cal-Trans employee in Eureka, California, developed a means of anchoring guardrails underneath the roadway. He used cantilevered steel I Beams set into ditches under the roadbed. To these he bolted steel risers on which to mount the rails. This design won him an award and also made possible the massive guardrail project which occurred beginning in late 1985 and continuing through 1986. In addition to the guardrails, some areas received very extensive widening and roadbed improvement. Some of these improvements are continuing today within our response area.

Questions

1. Have the guardrails affected the fatalities associated with over-the-bank motor vehicle crashes?

2. Have the guardrails caused other problems such as increased incidence of head-on crashes to occur?

3. Will the cantilevered guardrail design prove to be sturdy enough to withstand major impacts?

4. Are there still unprotected cluster sites and potential cluster sites which have not been discovered?

Methods

A fatality was defined as a death occurring within one year of a crash. Roadways were limited to those state highways, local roads, and major spur roads within the approximately 50-mile radius which constitutes the Hoopa Health Association EMS response zone. An embankment was any terrain feature beyond the shoulder of the road with a negative gradient sufficient to prevent the return of a vehicle to the roadway during a crash. An "over-the-embankment motor vehicle crash, or "over the banks" (OTBS) crash, was one in which a motor vehicle left the roadway and went down an embankment.

Data was recorded from the Hoopa Health Association Emergency Medical Rescue reports. I made site visits with video equipment to determine slope, embankment features, shoulder widths, and skid-mark patterns. I did not take measurements at the sites. From library files, I reviewed The Kourier (the local newspaper) for information on crashes. Additional data was obtained from California Department of Transportation post mile identification lists, US Geological Survey topographic maps, interviews with EMS personnel, and my personal familiarity with most of the cases as an on-scene paramedic/rescuer.

Results

The characteristics of several cluster sites are outlined in Table 1. The surveillance data indicates that there is a very strong correlation between the time guard-rails were installed and the reduction in over-the-bank vehicle crashes.(Table 2) There is no evidence to suggest any upswing in head-on crashes exacerbated by the guardrails. There has been only one head-on crash since 1985 and guardrails were not a factor.

To date, the cantilevered railing design seems to be holding up very well. There is much evidence of "brushing" impacts without any failures. In addition, these installations are able to take impacts by tumbling rocks without showing any obvious signs of weakening. I have yet to see any solid impacts on these rails, but I strongly suspect that they will hold up better than wood.

There are definitely still many unprotected embankments throughout this region. There are also some areas in which guardrails weren't installed completely around dangerous turns, leaving a gap in the area of the curve which is very likely to collect vehicles. These areas will continue to be especially hazardous until they are improved. However, the worst of the areas have been vastly improved.

Discussion

A simple, cheap and low-technology surveillance was undertaken which was able to accurately predict over-the-embankment vehicle crash clustering. This sort of "Hashmark" epidemiology could be easily applied by lay people with very little resources. The only prerequisite is access to useful information. In my case, it was extremely helpful to me that I was directly involved in the emergency services rendered at the scene of these crashes. It gave me a much clearer picture of exactly what the problems were. It also allowed me to begin to make comparisons in my own mind regarding exactly what was causing the problems. I would suggest that a little time spent tracking down people who have personal knowledge about the particular problem will save a lot of time and energy, and will assure a good start without too many delays and false starts.

By undertaking this surveillance, I was able to demonstrate how severe the problem really was in our area and, hopefully, make it more visible to those people who have the resources and responsibility to correct it. I see that the visibility of the problem is one of the most important parts of this program. Hazards need to be brought out into the open so that they can be identified, researched, and corrected. The nation needs to be made aware of the huge injury problem. Any method of getting that point across should be a priority.

In over-the-embankment crashes, multiple-system trauma (major trauma to more than one essential organ system) is almost always the killer. In most of the "on the roadway" crashes that I studied, multiple system trauma also was the major cause of death. The reason that the percentage of patients dying from over the banks was so much greater is that over the banks are much more likely to cause this type of trauma and the irreversible shock syndrome which goes with it. Almost all of the fatal over the banks that were studied involved ejection from the vehicle during a long sustained rollover crash. Often, the patient was found quite a distance from the crashed vehicle, indicating a "launching" effect and the lack of seatbelts.

In those rare cases that a seatbelt is worn, chances for survival seem to be much higher. There is a story, told to me by the survivors, about a woman who literally drove her car to the river over one of the less extreme bluff areas. Neither she nor her 65 year-old husband were injured. Finally, my observations predictably agree with the other experts regarding common features in-over-the-bank crashes:

Environment: Downhill grade frequently from both directions. Shady area that stays slippery much of the year. Poor road surface and debris on the roadway common. Poor visibility and inadequate marking of the turn. Changeable weather. Sharp turns with narrow shoulders and steep embankments.

Driver: Young. Speeding for conditions. Familiar with the road. Local. Male. Impaired by drugs, alcohol, or sleepiness.

Profile: Usually goes off the right side of the road during the crash. Either overcorrects more than once, or shows centrifical skid patterns associated with too much speed for traction.

It is the author's hope that this report will interest some of you in the modification of environmental factors as a useful alternative to trying to teach people how to protect themselves. One thing about a guardrail. If you need it and it's there, you'll be glad that it was. If you don't need it, it'll be there for the next guy.

References:

1. Fatal injury. Federal Highway Administration and the National Center for Health Statistics.
2. Wright PH, Hall JW, Zador PL: Low-cost countermeasures for ameliorating run-off road crashes. Washington, DC, Insurance Institute for Highway Safety, 1984.
3. Baker SP, O'Neill B, Karpf RS: The Injury Fact Book. IIHS, 1984.
4. Hall JW, et al: Roadside hazards on non- freeway facilities. Transportation Research Records 610, Transportation Research Board, 1976.
5. Oglesby CH: Highway Engineering. Third Edition.

Table 1: Characteristics of over-the-bank crash sites.

Site	Speed limit	Embankment grade	Slope	Shoulder width	Crash characteristics
North Hoopa Bluffs (16.98)	Not marked.	Extreme.	Sl. N. rise.	Very narrow.	Slippery conditions, excess speed, over 500 fall into the river.
Blue Slide Highway 96	40 mph in turn.	Extreme.	Level.	Under 10 feet.	Vehicle enters from N. at high speed. turns right, goes left into river.
South Hoopa Bluffs	Not known.	Extreme.	Sl. N. downhill.	None (logs).	Vehicle enters form S, turns L, goes R, OTB into river. Debris a factor.
East Fork Highway (299)	Trucks under 40 mph.	Very steep. .	Mod. E. downhill.	Narrow, with guardrails.	Truck enters from W, speeding, turns L, goes R through guardrail into 30' ditch. Icy conditions.
Mile Post 2.1, Trinity County 299	55 mph.	Very steep.	Downhill from E and W.	Narrow at apex of turn. Berm.	Wet roadway, vehicle leaves road at inside of turn, falls 200 feet.
McDonald's Bluffs (299) Burnt Ranch Area	55 mph.	Extreme.	Downhill from E and W.	Narrow at apex of turn. Gap in guard rail.	West-bound vehicle turns R, goes through gap in guardrail, falls 300 feet.
South Fork Road, Trinity County	Not marked.	Very steep. Wooded.	Downhill from E.	10-15 feet.	West-bound vehicle doesn't slow for poorly-marked turn at bottom of hill. Turns L, goes straight.

Table 2: Bluff Area deaths and injuries by year of occurrence (guard-rail installation was 1985-1986)

	1979*	1980	1981	1982	1983	1984	1985	1986	1987	1988
Deaths	5	9	2	1	5	0	1	1	0	0
Critical injuries	-	2	1	1	2	0	2	2	0	0
Minor injuries	-	1	1	1	1	0	0	1	0	0
TOTAL	5	12	4	3	8	0	3	4	0	0

*Based on personal EMS experience; no official records.